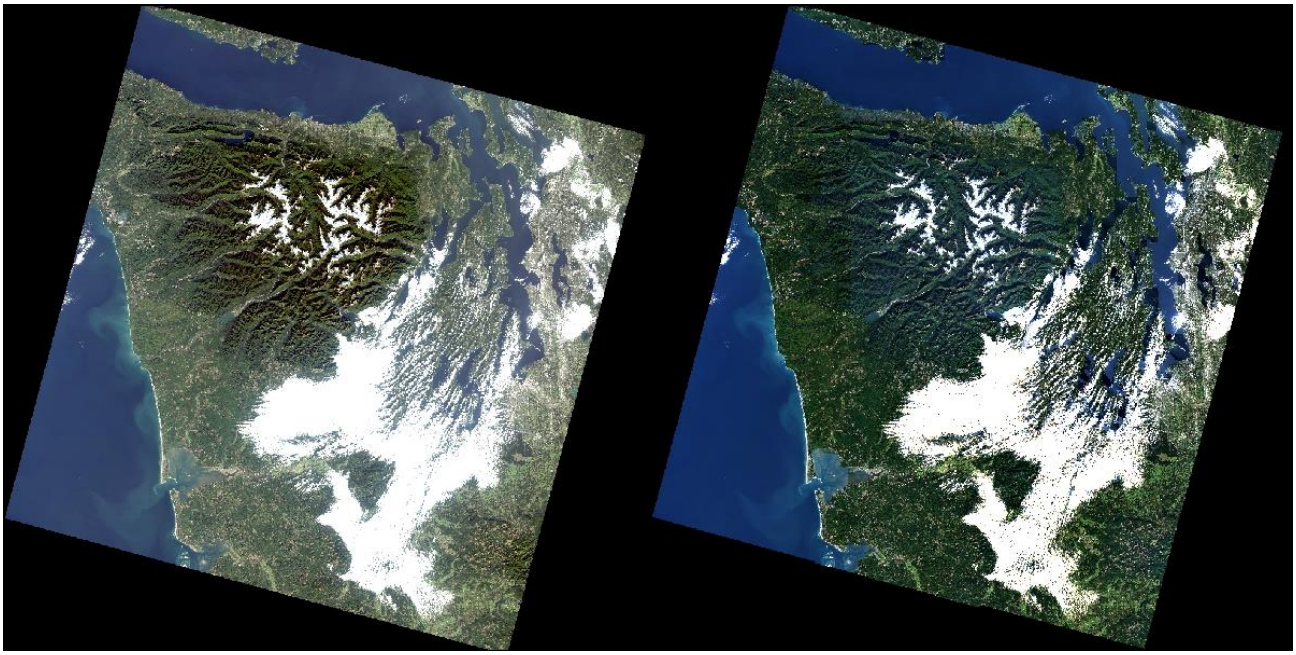
Department of the Interior
U.S. Geological Survey

PRODUCT GUIDE

PROVISIONAL LANDSAT 8 SURFACE REFLECTANCE CODE (LASRC) PRODUCT



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USGS
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Executive Summary

This document describes relevant characteristics of the Provisional Landsat 8 Surface Reflectance Code (LaSRC) Climate Data Record to facilitate its use in the land remote sensing community.

This document describes Top of Atmosphere Reflectance and Brightness Temperature derived from Landsat 8 Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS), respectively. Surface Reflectance can be derived only for OLI data. Other processing options, such as spectral indices, format conversion, spatial subset, and/or coordinate system reprojection are described in other product guides.

Document History

Document Version	Publication Date	Change Description
Version 1.0	12/18/2014	Initial Draft
Version 1.1	01/09/2015	Addition of “Known Issues” section.
Version 1.2	03/04/2015	Update to “Known Issues” section with additional information concerning improvements to aerosol retrieval. Update to aerosol bit value descriptions in Table 7-C. Corrected error in Bands 10-11 Brightness Temperature table.
Version 1.3	05/13/2015	Update to “Known Issues” section with additional information concerning improvements to land/water masking. Addition of provisional CFmask cloud confidence band.
Version 1.4	06/08/2015	Clarification of Bands 10-11 Brightness Temperature output.
Version 1.5	07/16/2015	Fixed broken reference.
Version 1.6	09/02/2015	Removed incorrect “_bt” file naming convention from Brightness Temperature description.
Version 1.7	9/21/2015	Added details to caveat describing high latitudes.
Version 1.8	12/01/2015	Added details about TIRS zero-fill data. Added changes to location of SR products on EE. Corrected minor typos and revised the formatting of citations.
Version 1.9	02/10/2016	Edited instances where “shadow” should be “cloud shadow” (in reference to CFmask).
Version 2.0	03/01/2016	Fixed broken L8 QA Band hyperlink. Updated source code links to Github pages.
Version 2.1	05/10/2016	Updates to “Known Issues” and “Caveats and Constraints” sections. Added citation for manuscript describing L8SR’s algorithm creation and initial analysis.
Version 3.0	07/01/2016	Changed name from “L8SR” to “LaSRC”. Fixed nearly all “blockiness” by interpolating missing aerosol data points. A new aerosol interpolation QA band (sr_ipflag) is now provided to show where aerosols have been interpolated versus actual observations. Reflectance is now retrieved over all pixels except those contaminated with cirrus. Added date restriction caveat for when MODIS Terra was in safe mode.
Version 3.1	08/23/2016	Added missing auxiliary data gaps dates.
Version 3.2	09/08/2016	Changed cloud confidence bits to actual representation – “low”, “medium” and “high”.

Version 3.3	10/11/2016	Added specifics on Known Issues, added NetCDF file format.
Version 3.4	12/07/2016	Replaced links to Landsat Missions Website

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Section 1 Introduction

Landsat satellite data have been produced, archived, and distributed by the U.S. Geological Survey (USGS) since 1972. Users rely upon these data for historical study of land surface change but shoulder the burden of post-production processing to create applications-ready data sets. To alleviate this burden, USGS has embarked on production of higher level Landsat data products to support land surface change studies. Terrestrial variables such as surface reflectance and land surface temperature, 30-meter land cover, burned area extent, snow covered area, and surface water extent will be offered as high-level products. These products will offer a framework for producing long-term Landsat science data collections suited for monitoring, assessing, and predicting land surface change over time.

The product described here, the Provisional Landsat 8 Surface Reflectance Code (LaSRC) is distinctly different from the algorithm used by USGS to process Landsat 4–5 Thematic Mapper (TM) and Landsat 7 Enhanced Thematic Mapper Plus (ETM+) Level-1 products to Surface Reflectance, known as the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS). Details of these differences are described below in **Table 1-A**. Please remember that LaSRC is provisional software, and the values are subject to change.

LaSRC's original development and preliminary characterization is documented in the peer-reviewed manuscript published by Vermote et al., 2016. Please see **Section 11 References** for more details.

Table 1-A Differences between Landsat 4–7 and Landsat 8 Surface Reflectance algorithms

6S Second Simulation of a Satellite Signal in the Solar Spectrum, AOT Aerosol Optical Thickness, CFmask C Version of Function Of Mask, CMA Climate Modeling Grid - Aerosol, CMG Climate Modeling Grid, DDV Dark Dense Vegetation, DEM Digital Elevation Model, ETM+ Enhanced Thematic Mapper Plus, GSFC Goddard Space Flight Center, INT Integer, LaSRC Landsat Surface Reflectance Code, LEDAPS Landsat Ecosystem Disturbance Adaptive Processing System, MEaSUREs Making Earth Science Data Records for Use in Research Environments, MODIS Moderate Resolution Imaging Spectroradiometer, N/A Not Applicable, NASA National Aeronautics and Space Administration, NCEP National Centers for Environmental Prediction, OLI Operational Land Imager, OMI Ozone Monitoring Instrument, QA Quality Assurance, SR Surface Reflectance, TIRS Thermal Infrared Sensor, TM Thematic Mapper, TOA Top of Atmosphere Reflectance, TOMS Total Ozone Mapping Spectrometer, XML Extensible Markup Language

Parameter	Landsat 4–5, 7 (LEDAPS)	Landsat 8 OLI (LaSRC)
(Original) research grant	NASA GSFC, MEaSUREs (Masek)	NASA GSFC
Global coverage	Yes	Yes
TOA	Visible (1–5,7) + Brightness temp (6) bands	Visible (1–7, 9) +Thermal (10–11) bands
SR	Visible (1–5, 7) bands	Visible (1–7) bands (OLI/TIRS only)
Radiative transfer model	6S	Internal algorithm
Thermal correction level	TOA only	TOA only
Thermal band units	Kelvin	Kelvin

Pressure	NCEP Grid	Surface pressure is calculated internally based on the elevation
Water vapor	NCEP Grid	MODIS CMA
Air temperature	NCEP Grid	MODIS CMA
DEM	Global Climate Model DEM	Global Climate Model DEM
Ozone	OMI/TOMS	MODIS CMG Coarse resolution ozone
AOT	Correlation between chlorophyll absorption and bound water absorption of scene	MODIS CMA
Sun angle	Scene center from input metadata	Scene center from input metadata
View zenith angle	From input metadata	Hard-coded to 0
Undesirable zenith angle correction	SR not processed when solar zenith angle > 76 degrees	SR not processed when solar zenith angle > 76 degrees
Pan band processed?	No	No
XML metadata?	Yes	Yes
Brightness temperature calculated	Yes (Band 6 TM/ETM+)	Yes (Bands 10 & 11 TIRS)
Cloud mask	Internal algorithm; CFmask	Internal algorithm; CFmask
Data format	INT16	INT16
Fill values	-9999	-9999
QA bands	Cloud Adjacent cloud Cloud shadow DDV Fill Land water Snow Atmospheric opacity	Cloud Adjacent cloud Cloud shadow Aerosols Cirrus Aerosol Interpolation Flag

Section 2 Known Issues

2.1 Surface Reflectance Artifacts

The artifacts present in Surface Reflectance data products obtained before July 1, 2016 product have been largely eliminated. The artifacts, or “blockiness” was largely caused by the Global Climate Modeling (GCM) grid’s aerosol values not being correctly interpolated to the Landsat grid, causing grid-shaped artifacts. To prevent this, LaSRC now interpolates missing aerosol grid values to fit continuously within the Landsat grid cells. While making the resulting data product appear more consistent, interpolated values are not direct measurements, therefore an Interpolation Flag QA band (sr_ipflag) is now provided with the Surface Reflectance data product (**Section 7.1.5**).

Previous interpolation issues along coastal water bodies led us to implement a land/water mask to better identify coastal waters, since aerosols were not being retrieved over coastal waters and this resulted in significant blockiness along the coastal areas. Given the change in the new version of LaSRC to attempt aerosol retrieval over all pixels, the higher resolution land/water mask has been removed.

There is a known bug causing pixels flagged as cirrus to be processed, resulting in pixel values being assigned as 0.0. This issue is actively being investigated. In the interim, users are advised to use pixels that are not flagged as cirrus, as indicated in the sr_cloud band provided with the Surface Reflectance data product (**Section 7.1.1**).

Please see https://landsat.usgs.gov/sites/default/files/documents/lasrc_release_notes.pdf for more information pertaining to the algorithm updates.

Section 3 Caveats and Constraints

1. The LaSRC algorithm has not been completely validated; the algorithm and its subsequent output products are considered provisional.
2. Corrections from OLI Bands 1 and 2 (coastal aerosol and blue bands, respectively) should not be used for analysis, as they are already used within the algorithm to perform aerosol inversion tests, making them potentially unreliable.
3. Landsat 8 data cannot be processed to Surface Reflectance between dates:
    - 2016-050 (February 19, 2016) and 2016-058 (February 27, 2016) due to MODIS Terra entering safe mode. MODIS Terra data are used to create the climate grids used for the atmospheric characterization components of LaSRC.
    - 2016-221 (August 11, 2016) and 2016-223 (August 13, 2016) due to an issue with MODIS Aqua L0 production.
4. Aerosol interpolation is only attempted over pixels meeting certain conditions:
    - Aerosols are not retrieved over pixels identified as cirrus cloud.
    - The retrievals are then tested based first on the model residual and then on the NDVI combined with band 5 reflectance. If these tests fail, then the pixel is marked as failed for aerosol retrieval.
    - Any pixel which failed retrieval is ultimately attempted to be interpolated.
    - Water pixels (flagged if the NDVI < 0.01), cloud pixels, and cirrus pixels are not interpolated.
    - The final reflectance corrections are applied using the retrieved/interpolated aerosols.
5. Surface Reflectance cannot be run on Landsat 8 Pre-Worldwide Reference System (WRS)-2 scenes. More information about Pre-WRS-2 scenes can be found at https://landsat.usgs.gov/what-landsat-8-olitirs-pre-wrs-2-data.
6. Although Surface Reflectance can be processed only from the Operational Land Imager (OLI) bands, SR requires combined OLI/Thermal Infrared Sensor (TIRS) product (LC8) input in order to generate the accompanying cloud mask. Therefore, OLI only (LO8), and TIRS only (LT8) data products cannot be calculated to SR.
7. SR is not run on scenes with a solar zenith angle of greater than 76º. The primary physical issues with retrieving SR from high solar zenith angles (low sun angle) include:
    - Solar elevation varies more near the poles [1], especially when relying upon sun-synchronous observations.
    - Lower solar elevations at high latitudes results in longer atmospheric paths (i.e. more scattering) [1].

- The degree of uncertainty in SR retrieval greatly increases, from being negligible to highly inaccurate, at or above a solar zenith angle > 76 degrees.

References: [1] Campbell, J. W., & Aarup, T. (1989). Photosynthetically available radiation at high latitudes. Limnology and Oceanography, 34(8), 1490-1499. http://dx.doi.org/10.4319/lo.1989.34.8.1490.

8. For reasons mentioned above, users are cautioned against processing data acquired over high latitudes (> 65º) to Surface Reflectance.
9. Users are cautioned against using pixels flagged as high aerosol content. See **Table 7-C** for details.
10. There are additional adverse conditions that can affect the efficacy of L8SR retrievals, such as:
    - Hyper-arid or snow-covered regions
    - Low sun angle conditions
    - Coastal regions where land area is small relative to adjacent water
    - Areas with extensive cloud contamination.
11. OLI Band 8 (panchromatic band) is not processed to Top of Atmosphere or Surface Reflectance.

Section 4 Product Options

This product guide is specific only to the products listed below. Options for processing other Landsat data are covered in separate product guides.

1. Original Input Products
2. Original Input Metadata
3. Top of Atmosphere (TOA) Reflectance (all bands except Panchromatic Band 8) .
4. Brightness Temperature (calculated from at-sensor radiances to calculate the corresponding TOA Brightness Temperature, or simply referred to as “Brightness Temperature”. These are separate products generated for Bands 10 and 11).
5. Surface Reflectance (all bands except Panchromatic Band 8, Cirrus Band 9, and Thermal Bands 10 and 11).

These products are available for any Landsat 8 data product available in the USGS archive, with the exceptions noted in **Section 3 Caveats and Constraints.**

4.1 Original Input Products

Selection of this option delivers the original unaltered Landsat 8 Level-1 data product, which contains:

- Level-1 data files (Bands 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11)
- Quality Assessment (QA) Band file (https://landsat.usgs.gov/qualityband)
- Metadata text file (MTL.txt)

Filenames utilize the original scene identifier (sceneID), for example, “LC80270332014310LGN00_*.” Product details are found at https://landsat.usgs.gov/landsat-8.

4.2 Original Input Metadata

The Landsat 8 Level-1 metadata (MTL.txt) will be distributed when this option is requested.

4.3 Top of Atmosphere Reflectance

This option calculates TOA Reflectance from the Original Input Landsat scene. Further details are given in **Section 7 Product Characteristics**.

Top of Atmosphere Reflectance output from Landsat 8 contains:

- LC8 data: TOA Reflectance data files (Bands 1–7, 9)
- LO8 data: TOA Reflectance data files (Bands 1–7, 9)
- TOA Reflectance header files
- TOA Reflectance metadata file (.xml)

Filenames utilize the original sceneID followed by "_toa_," for example, "LC80180602014247LGN00_toa_*."

4.4 Brightness Temperature

This option delivers the Top of Atmosphere Brightness Temperature product (Bands 10 and 11), which are converted to Kelvin. Brightness Temperature output from Landsat 8 contains:

- LC8 data: Brightness Temperature data files (Bands 10–11)
- LT8 data: Brightness Temperature data files (Bands 10–11)
- Brightness Temperature header files
- Brightness Temperature metadata file (.xml)

Filenames utilize the original sceneID followed by "_toa_," for example, "LC81710612014183LGN00_toa_*."

4.5 Surface Reflectance

This option delivers the Surface Reflectance product, without the TOA Reflectance or the original input files. **Section 7 Product Characteristics** describes the product in full detail. General contents are listed below.

Landsat Surface Reflectance output from Landsat 8 contains:

- Surface Reflectance data files (Bands 1–7)
- Cloud QA band (see **Section 7.1.1** for more details)
- Cloud mask (CFmask) band (see **Section 7.1.2** for more details)
- CFmask cloud confidence band (see **Section 7.1.3** for more details)
- Interpolation Flag QA band (see **Section 7.1.5** for more details)
- Surface Reflectance metadata file (.xml)

Filenames utilize the original sceneID followed by "_sr_," for example, "LC82330132014265LGN00_sr_*."

4.6 Spectral Indices

Landsat 8 Surface Reflectance can be used to derive several spectral index products, as listed below. Their characteristics are described in a separate product guide for Landsat 4–8 (see Landsat Spectral Indices Product Guide) and currently include:

- Normalized Difference Vegetation Index (NDVI)
- Enhanced Vegetation Index (EVI)
- Soil Adjusted Vegetation Index (SAVI)
- Modified Soil Adjusted Vegetation Index (MSAVI)
- Normalized Difference Moisture Index (NDMI)
- Normalized Burn Ratio (NBR)
- Normalized Burn Ratio 2 (NBR2)

Section 5 Product Access

Provisional Landsat 8 Surface Reflectance data products are available through EarthExplorer, under the “Data Sets” > “Landsat Archive” tabs as “Landsat Surface Reflectance – L8 OLI/TIRS”.

An on-demand interface called ESPA (U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA)) offers Landsat 8 Surface Reflectance in addition to Original Input Products and Metadata, TOA Reflectance, NDVI, NDMI, NBR, NBR2, SAVI, MSAVI, and EVI data products. Services such as reprojection, spatial subsetting, and pixel resizing are also available through ESPA. ESPA is accessible at https://espa.cr.usgs.gov/. Additional information about ESPA’s spectral indices and service processing options for Landsat 4–8 can be found in the Spectral Indices Product Guide and ESPA On-Demand Interface User Guide, respectively.

Section 6 Product Packaging

Surface Reflectance products are supplied in a gzip file (.tar.gz). Unzipping this file produces a tarball (.tar), which will “untar” to a Georeferenced Tagged Image File Format (GeoTIFF; .tif) file. The filenames are structured as the original scene ID appended with the suffix “_sr_” followed by a band designation to denote the Surface Reflectance transformation. Following are the components of a typical file:

LXXPPPRRRYYYYDDDSTNVR_prod_band.ext
(e.g., LC80120542014301LGN00_sr_band1.tif)

LXX	LC8 for Landsat 8 OLI and TIRS
PPP	Path
RRR	Row
YYYY	Year of Acquisition
DDD	Julian Date of Acquisition
STN	Receiving Station
VR	Version Number
prod	Product, such as “toa” or “sr”
band	Band, such as “band<1-8, 10-11>,” “qa,” or spectral index.
ext	File format extension, such as “tif,” “tfw,” “xml,” “hdf,” “hdr,” or “img”

Section 7 Product Characteristics

Original Input Products and Original Input Metadata are described on https://landsat.usgs.gov/landsat-processing-details. The characteristics of Surface Reflectance, TOA Reflectance, and Brightness Temperature are detailed in the following sections.

7.1 Surface Reflectance Specifications

The Landsat 8 Surface Reflectance product is generated at 30-meter spatial resolution on a Universal Transverse Mercator (UTM) or Polar Stereographic (PS) mapping grid. The default file format is GeoTIFF, but options for delivery in Hierarchical Data Format – Earth Observing System – 2 (HDF-EOS-2; .hdf), NetCDF (.nc) or ENVI binary (.img) are available through the ESPA Ordering Interface. More information on output formats currently used for Landsat 4–8 can be found in the ESPA On Demand Interface User Guide.

Landsat 8 Surface Reflectance will be delivered in files named with the original sceneID and appended with "_sr_" followed by a band designation. All packages include Extensible Markup Language (xml)-based metadata.

The Surface Reflectance bands are delivered in separate, condition-specific files, with the exception of the Cloud QA Band, which is delivered in a single bit-packed layer. **Table 7-A** lists the specifications for the bands included in a Surface Reflectance data file.

Table 7-A Surface Reflectance Specifications

INT16 16-bit signed integer, UINT8 8-bit unsigned integer, QA quality assurance, CFmask C version of Function of Mask, NA not applicable

Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
sr_band1	Band 1	INT16	Reflectance	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band2	Band 2	INT16	Reflectance	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band3	Band 3	INT16	Reflectance	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band4	Band 4	INT16	Reflectance	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band5	Band 5	INT16	Reflectance	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band6	Band 6	INT16	Reflectance	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band7	Band 7	INT16	Reflectance	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_cloud	Cloud QA	UINT8	Flag	0-7	0-7	NA	NA	NA
sr_ipflag	Interpolation Flag	UINT8	Flag	0-6	0-6	NA	NA	NA
sr_cfmask	CFmask	UNIT8	Flag	0-255	0-4	255	NA	NA
sr_cfmask_conf	CFmask Cloud Confidence	UINT8	Flag	0-255	0-4	255	NA	NA

7.1.1 Cloud QA Specifications

The Landsat 8 Surface Reflectance product includes the "sr_cloud" band. This product details the presence of clouds and levels of aerosols and is used to determine the level

of surface reflectance correction to apply to each pixel. The interpretation of each bit as shown in the XML metadata file is described in **Table 7-B**.

Three interpreted bit values within this band indicate the level of aerosols and subsequent surface reflectance correction applied to each pixel. **Table 7-C** shows the values and levels found within the “sr_cloud” band.

Table 7-B Cloud QA Bit Values

Bit	Interpretation
0	Cirrus cloud
1	Cloud
2	Adjacent to cloud
3	Cloud shadow
4	Aerosol
5	Aerosol
6	Unused
7	Internal test

Table 7-C Cloud QA Interpreted for Aerosol QA Bits 4-5

Value	Interpretation
00	Climatology-level aerosol content
01	Low aerosol content
10	Average aerosol content
11	High aerosol content

Note that pixels classified as high aerosol content are not recommended for use.

7.1.2 CFmask Specifications

The Landsat 8 Surface Reflectance product includes an alternative to cloud, cloud shadow, snow, and water identification, and is likely to present more accurate results than its companion bands (cloud_qa). The CFmask band was originally developed at Boston University in a Matrix Laboratory (MATLAB) environment to automate cloud, cloud shadow, and snow masking for Landsat TM and ETM+ images. The MATLAB Function of Mask (Fmask) was subsequently translated into open source C code at the USGS EROS Center, where it is implemented as the C version of Fmask, or CFmask (https://github.com/USGS-EROS/espa-cloud-masking).

CFmask designates whether clouds, cloud shadows, snow, or water were identified in each pixel in the Surface Reflectance product, as described by **Table 7-D**

Table 7-D CFmask Pixel Values

CFmask C version of Function of Mask

Pixel Value	Interpretation
255	Fill
0	Clear

1	Water
2	Cloud shadow
3	Snow
4	Cloud

7.1.3 CFmask Cloud Confidence Band

A confidence band for the cloud detection portion of CFmask is provided with the Landsat 8 Surface Reflectance product. The output of this band are considered provisional, as the confidence thresholds are subject to change. **Table 7-E** describes each value within the CFmask Confidence Band.

Table 7-E CFmask Cloud Confidence Band Values

Pixel Value	Interpretation
255	Fill
0	None
1	Low cloud confidence
2	Medium cloud confidence
3	High cloud confidence

7.1.4 Surface Reflectance Metadata

Each Landsat 8 Surface Reflectance order will be accompanied by an xml-based metadata file. The metadata fields included in the xml are listed in **Appendix B Metadata Fields**.

7.1.5 Interpolation Flag QA Band

Due to gaps in the climate grid, not all aerosol values are direct observations, but are instead partially interpolated to fit to the Landsat data. While this creates a more continuous data product, interpolation inevitably introduces more uncertainty. Here an Interpolation Flag QA band (sr_ipflag) is provided to indicate which aerosol pixel(s) are interpolated versus direct observation. Table 7-F describes each value within the Interpolation Flag QA Band.

Table 7-F Interpolation Flag QA Band Values

Pixel Value	Interpretation
0	Aerosol retrieval successful
1	Aerosol retrieval failed, but aerosol was interpolated
2	NDVI test failed, but aerosol was not interpolated
3	Residual test failed, but aerosol was not interpolated
4	Not used
5	Fill pixel
6	Water pixel

7.1.6 Surface Reflectance Special Notes

Metadata are included to help define the orientation of Polar Stereographic scenes acquired in ascending orbit over Antarctica. Whether on a descending or ascending orbit path, the first pixels acquired in a Landsat scene comprise the upper portion of an image. As Landsat crosses the southern polar region, it views the southern latitudes first and progresses north. This places pixels in southern latitudes in the upper part of the image so that it appears to the user that south is up and north is down. The <corner> field in the metadata xml clarifies the upper left and lower right corners of the scene.

7.2 Top of Atmosphere Reflectance Specifications

7.2.1 Top of Atmosphere Reflectance - Bands 1–7, 9 Specifications

Calibration coefficients are applied to Landsat digital numbers to derive the TOA Reflectance component, using scene center solar angles in the computation. All files appended with "_toa_" are related to TOA Reflectance. The "_toa_" packages contain TOA Reflectance and bit-packed quality information for Landsat Bands 1, 2, 3, 4, 5, 6, 7, and 9. The associated header and metadata files present the same kind of information as described for Surface Reflectance, but these are specific to TOA Reflectance processing. Valid data ranges for TOA Reflectance bands are similar to those for Surface Reflectance, but with a higher minimum value. Note: TOA Reflectance is not processed for thermal Bands 10 and 11, but can be ordered separately as Brightness Temperature (**Section 7.2.2**).

Table 7-G lists the data type, units, value range, fill value, saturation value, and scale factor for the TOA Reflectance product bands.

Table 7-G Top of Atmosphere Reflectance – Bands 1-7, 9 Specifications

INT16 16-bit signed integer, UINT8 8-bit unsigned integer, TOA top of atmosphere, QA quality assurance, NA not applicable

Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
toa_band1	Band 1 Reflectance	INT16	Reflectance	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band2	Band 2 Reflectance	INT16	Reflectance	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band3	Band 3 Reflectance	INT16	Reflectance	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band4	Band 4 Reflectance	INT16	Reflectance	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band5	Band 5 Reflectance	INT16	Reflectance	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band6	Band 6 Reflectance	INT16	Reflectance	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band7	Band 7 Reflectance	INT16	Reflectance	-100 – 16000	0 – 10000	-9999	20000	0.0001

toa_band9	Band 9 Reflectance	INT16	Reflectance	-100 – 16000	0 – 10000	-9999	20000	0.0001

7.2.2 Brightness Temperature - Bands 10–11 Specifications

Bands 10–11 Brightness Temperature is derived from TOA radiance and two thermal constants, as described at https://landsat.usgs.gov/using-usgs-landsat-8-product. The associated header and metadata files present the same kind of information as described for Surface Reflectance, but they are specific to Brightness Temperature processing. Specifications for Brightness Temperature bands are similar to those for Surface Reflectance, but with a higher minimum value. **Table 7-H** lists the data type, units, value range, fill value, saturation value, and scale factor for the Brightness Temperature product bands.

Table 7-H Top of Atmosphere Brightness Temperature – Bands 10–11 Specifications

INT16 16-bit signed integer, UINT8 8-bit unsigned integer, TOA top of atmosphere, QA quality assurance, NA not applicable

Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
toa_band10	Band 10 Brightness Temperature	INT16	Brightness Temperature (Kelvin)	-100 - 16000	0-10000	-9999	20000	0.1
toa_band11	Band 11 Brightness Temperature	INT16	Brightness Temperature (Kelvin)	-100 - 16000	0-10000	-9999	20000	0.1

7.2.3 TOA Reflectance Special Notes

Metadata are included to help define the orientation of Polar Stereographic scenes acquired in ascending orbit over Antarctica. Whether on a descending or ascending orbit path, the first pixels acquired in a Landsat scene comprise the upper portion of an image. As Landsat crosses the southern polar region, it views the southern latitudes first and progresses north. This places pixels in southern latitudes in the upper part of the image so that it appears to the user that south is up and north is down. The <corner> field in the metadata xml clarifies the upper left and lower right corners of the scene.

Section 8 Citation Information

There are no restrictions on the use of these high-level Landsat products. It is not a requirement of data use, but the following citation may be used in publication or presentation materials to acknowledge the USGS as a data source and to credit the original research.

Landsat Surface Reflectance products courtesy of the U.S. Geological Survey.

Vermote, E., Justice, C., Claverie, M., & Franch, B. (2016). Preliminary analysis of the performance of the Landsat 8/OLI land surface reflectance product. Remote Sensing of Environment. http://dx.doi.org/10.1016/j.rse.2016.04.008.

Reprints or citations of papers or oral presentations based on USGS data are welcome to help the USGS stay informed of how data are being used. These can be sent to the User Services address included in this guide.

Section 9 Acknowledgments

The original Landsat 8 Surface Reflectance algorithm was developed by Dr. Eric Vermote, NASA Goddard Space Flight Center (GSFC).

The original CFmask software, Fmask, was developed at the Center for Remote Sensing in the Department of Earth and Environment at Boston University, and is available from https://github.com/prs021/fmask.

Section 10 User Services

Landsat high-level products and associated interfaces are supported by User Services staff at USGS EROS. Any questions or comments regarding data products or interfaces are welcomed through the Landsat “Contact Us” online correspondence form: https://landsat.usgs.gov/contact. E-mail can also be sent to the customer service address included below, with the same indication of topic.

USGS User Services
https://landsat.usgs.gov/contact
custserv@usgs.gov

User support is available Monday through Friday from 8:00 a.m. – 4:00 p.m. Central Time. Inquiries received outside of these hours will be addressed during the next business day.

Section 11 References

Campbell, J. W., and Aarup, T. (1989). Photosynthetically available radiation at high latitudes. *Limnology and Oceanography* 34(8):1490- 1499. http://dx.doi.org/10.4319/lo.1989.34.8.1490.

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Zhu, Z., Wang, S., and Woodcock, C. E. (2015). Improvement and expansion of the Fmask algorithm: cloud, cloud shadow, and snow detection for Landsats 4–7, 8, and Sentinel 2 images. *Remote Sensing of Environment* 159:269-277. http://dx.doi.org/10.1016/j.rse.2014.12.014.

Appendix A Default File Characteristics

Table A-1 *Default File Characteristics*

Description	Example File Size (bytes)	Example File Name
Source Bands (11)	126,491,737	LC80430312013179LGN00_B*.tif
Source Band QA	126,491,737	LC80430312013179LGN00_QA.tif
Source Metadata	7,791	LC80430312013179LGN00_MTL.txt
TOA Reflectance Bands (8)	126,491,785	LC80430312013179LGN00_toa_band*.tif
TOA Brightness Temperature Bands (2)	126,491,785	LC80430312013179LGN00_toa_band*.tif
Surface Reflectance Bands (7)	126,491,751	LC80430312013179LGN00_sr_band*.tif
Surface Reflectance Cloud QA Band (1)	63,278,592	LC80430312013179LGN00_sr_cloud.tif
Surface Reflectance Interpolation Flag QA Band (1)	63,278,592	LC80430312013179LGN00_sr_ipflag.tif
CFmask Band	63,278,592	LC80430312013179LGN00_cfmask.tif
CFmask Cloud Confidence Band	63,278,592	LC80430312013179LGN00_cfmask_conf.tif
Metadata	23,532	LC80430312013179LGN00.xml

Appendix B Metadata Fields

Example of global XML metadata:

```
<global_metadata>
      <data_provider>USGS/EROS</data_provider>
      <satellite>LANDSAT_8</satellite>
      <instrument>OLI_TIRS</instrument>
      <acquisition_date>2013-06-28</acquisition_date>
      <scene_center_time>18:40:39.8204854Z</scene_center_time>
      <level1_production_date>2014-11-13T15:01:34Z</level1_production_date>
      <solar_angles zenith="24.733788" azimuth="131.660614" units="degrees"/>
      <wrs system="2" path="43" row="31"/>
      <lpgs_metadata_file>LC80430312013179LGN00_MTL.txt</lpgs_metadata_file>
      <corner location="UL" latitude="42.801350" longitude="-120.700400"/>
      <corner location="LR" latitude="40.691440" longitude="-117.783500"/>
      <bounding_coordinates>
         <west>-120.700594</west>
         <east>-117.783319</east>
         <north>42.858456</north>
         <south>40.638480</south>
      </bounding_coordinates>
      <projection_information projection="UTM" datum="WGS84" units="meters">
         <corner_point location="UL" x="197400.000000" y="4745400.000000"/>
         <corner_point location="LR" x="433800.000000" y="4504800.000000"/>
         <grid_origin>CENTER</grid_origin>
         <utm_proj_params>
            <zone_code>11</zone_code>
         </utm_proj_params>
      </projection_information>
      <orientation_angle>0.000000</orientation_angle>
   </global_metadata>
```

Example of per-band XML metadata:

```
<band product="sr_refl" name="sr_band1" category="image" data_type="INT16" nlines="8021"
nsamps="7881" fill_value="-9999" scale_factor="0.000100">
         <short_name>LC8SR</short_name>
         <long_name>band 1 surface reflectance</long_name>
         <file_name>LC80430312013179LGN00_sr_band1.tif</file_name>
         <pixel_size x="30" y="30" units="meters"/>
         <data_units>reflectance</data_units>
         <valid_range min="-2000" max="16000"/>
         <app_version>l8_surface_reflectance_0.1.0</app_version>
         <production_date>2014-11-13T15:42:29Z</production_date>
      </band>
```

Appendix C Acronyms

Acronym	Description
6S	Second Simulation of a Satellite Signal in the Solar Spectrum
CDR	Climate Data Record
CFmask	C version of Function of Mask (USGS EROS)
CMA	Climate Modeling Grid - Aerosols
CMG	Climate Modeling Grid - Ozone
CSV	Comma Separated Values
DDV	Dark Dense Vegetation
DIR	Directory
ECV	Essential Climate Variable
ENVI	Exelis Visual Information Solutions
EROS	Earth Resources Observation and Science
ESPA	EROS Science Processing Architecture
ETM+	Enhanced Thematic Mapper Plus
EVI	Enhanced Vegetation Index
Fmask	Function of Mask (Boston University)
GeoTIFF	Geographic Tagged Image File Format
GSFC	Goddard Space Flight Center
HDF-EOS2	Hierarchical Data Format – Earth Observing System (version 2)
HDR	Header
INT	Signed Integer
L8SR	Provisional Landsat 8 Surface Reflectance Algorithm (Note: no longer used)
LaSRC	Landsat Surface Reflectance Code
LDOPE	Land Data Operational Product Evaluation
LEDAPS	Landsat Ecosystem Disturbance Adaptive Processing System
LPGS	Landsat Product Generation System
LSB	Least Significant Bit
MATLAB	Matrix Laboratory
M	meter
MEaSUREs	Making Earth System Data Records for Use in Research Environments
MODIS	Moderate Resolution Imaging Spectroradiometer
MSAVI	Modified Soil Adjusted Vegetation Index
MSB	Most Significant Bit
NA	Not Applicable
NASA	National Aeronautic and Space Administration
NBR	Normalized Burn Ratio
NBR2	Normalized Burn Ratio 2
NC	NetCDF File Format
NCEP	National Centers for Environmental Prediction
NDMI	Normalized Difference Moisture Index
NDVI	Normalized Difference Vegetation Index

OLI	Operational Land Imager
OMI	Ozone Monitoring Instrument
PS	Polar Stereographic
QA	Quality Assurance
SAVI	Soil Adjusted Vegetation Index
sceneID	Scene Identifier
SLC	Scan Line Corrector
SR	Surface Reflectance
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
TOA	Top of Atmosphere
TOMS	Total Ozone Mapping Spectrometer
UINT	Unsigned Integer
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
WRS	Worldwide Reference System
xml	Extensible Markup Language